

MECHANICAL BEHAVIOR OF THE DIFFERENT SOILS UNDER THE SOIL- PILE INTERACTION

Amar Singh Kushwaha¹, Vinay Kumar Singh Chandrakar²

¹M. Tech. Scholar, Madhyanchal Professional University, Faculty of engineering & Technology, School of civil engineering Bhopal, M.P., India.

²Assistant Professor. Madhyanchal Professional University, Faculty of engineering and Technology, School of Civil Engineering, Bhopal, M.P, India.

ABSTRACT

The study focuses on the nonlinear interaction between soil, pile, and pile cap, particularly examining the behavior of soil and pile under working load conditions. The research utilizes ANSYS software to model an 8-story plane frame and a 2D plane of soil and pile, employing Beam188 and Plane 183 elements for the analysis. The beam-columns in the model are sized at 300mm x 300mm, while the piles have a diameter of 400mm with a pile cap width of 2m and thickness of 300mm. The study considers soil of medium stiffness with three different moduli of elasticity: E-15, E-35, and E-65. The frame is subjected to a combination of dead load, live load (40 kN/m), and seismic load according to IS:1893 (Part I):2002 for zone V. Finite Element Analysis (FEA) with contact surface pairing is used to evaluate the interaction between soil and pile. The analysis results are presented in terms of X-Displacement, Y-Displacement, von Mises stress contour, contact pressure, and their contact status. The study concludes that soil with a Young's modulus of elasticity E-35 demonstrates greater stiffness compared to soils with E-15 and E-65. These findings are illustrated graphically and through contour diagrams for each soil type. Finally, the study discusses the future scope of the project and provides references for further research.

Key Words: Non linear interaction, soil and pile, pile cap, ANSYS, stiffness and Finite Element Analysis.

1. INTRODUCTION

In case of the civil engineering structures foundation involves with direct contact with Soil. The foundation of a structure resting on a settleable soil mass under goes differential settlement which alters the forces in the structural elements significantly. In case of analysis of multistory building, the seismic loads and wind loads are necessary to take as design loads and the building frame, foundation and soil mass are considered to act as single, compatible structural unit. The linear or nonlinear behavior of soil mass is main cause of differential settlement which redistributes the forces in the elements of the structure mainly in the beams and column. When the external forces such as earthquake act on these systems, the structural displacements and the ground displacements both are independent of each other. The processing which the response of the soil affects the motion of the structure and the motion of the structure affects the response of the soil is termed as Soil-Structure Interaction (SSI).

Mmotivation Behind the study

The building frame and its foundation along with the soil on which it rests, together constitute a complete structural system. In the conventional analysis, a structure is analyzed as an independent frame assuming unyielding supports and the interactive response of soil foundations disregarded. This kind of analysis does not provide realistic behavior and sometimes may cause failure of structure. Thus it is essential to consider the soil-structure interaction effect especially in case of high rise buildings. The resulting differential settlements of soil mass are responsible for the redistribution of forces.

2. LITERATURE SURVEY

Francesco Cavalieri et al (2020) Dynamic Soil–Structure Interaction (SSI) involves the complex interaction between the soil, the foundation, and the structure, which is particularly challenging to model accurately, especially when considering soil nonlinearity. This paper assesses how different SSI models impact the seismic fragility functions of unreinforced masonry (URM) buildings on shallow foundations. The study concludes that different SSI models, particularly when accounting for soil nonlinearity, significantly influence the seismic fragility functions of URM buildings on shallow foundations. This highlights the importance of selecting appropriate SSI models in seismic assessments to ensure realistic predictions of structural performance during earthquakes. By comparing the linear substructure models with the nonlinear approach, the study evaluates how assuming linearity or nonlinearity in the soil affects the fragility assessment. The sensitivity of fragility functions to different SSI assumptions provides insights into the significance of accurately modeling soil behavior for seismic risk assessments. These are probabilistic tools used to

describe the likelihood of reaching or exceeding different levels of structural damage under varying seismic intensities. This simplification is crucial for focusing the analysis on the impact of SSI rather than the complexities of the superstructure itself.

Aldo Fernández Limés et al (2023) Soil-structure interaction (SSI) is a critical field of study within civil and structural engineering, with a rich body of literature detailing its effects on various types of buildings and structures. While the primary motivation for investigating SSI has traditionally been its impact during seismic events, it is crucial to acknowledge that other sources of excitation, such as wind forces, vibrations from machinery, and large static loads, can also significantly affect structures when conditions for SSI are present. The primary aim of this text is not to provide an exhaustive overview of all existing knowledge on SSI. Instead, it seeks to underscore the importance of SSI effects on different structures through illustrative case studies. These case studies demonstrate the consequences of SSI on structural response and present methods for analyzing these effects. Special emphasis is placed on non-seismic excitations, an area that, despite being equally significant, has not received as much attention as seismic studies. The text provides case studies that highlight the real-world implications of SSI under non-seismic excitations. These cases illustrate how neglecting SSI can lead to significant structural issues and demonstrate the benefits of incorporating SSI analysis into the design process. This work aims to inspire engineers and researchers to integrate SSI analysis into their projects more consistently, particularly for non-seismic excitations. By doing so, they can enhance the safety, performance, and longevity of structures. The text serves as both an educational resource and a motivational tool, encouraging the consideration of SSI in all relevant structural analyses.

Methodology and Finite Element Analysis on soil-Pile Interaction

The methodology adopted in modeling and analysis of an eight storey building frame has been discussed in this chapter. ANSYS software is used for analyzing the frame with and without considering structure-soil interaction. The overview of the program in the form of flow chart has been detailed.

Geometrical Properties

Table -1 Geometrical properties of the super structure and foundation

S.No	Structural components	Properties and size of the components
1.	All floor and plinth beam	0.3m*0.3m
2.	Columns	0.3m*0.3m
3.	Footings	2m*2m*1m
4.	Number of bays	3
5.	Number of storeys	8
6.	Floor beam and plinth beam uniformly distributed loading	40 kn/m
7.	Depth of soil	5.0 m

Material Properties The material of super-structure and foundation i.e. concrete is considered to behave in linearelastic manner. Table 2 shows the material properties of the structure and soil.

Table -.2 Material properties of the structure and soil

S. No.	Structural components	Properties and size of components
1.	Modulus of elasticity of concrete (N/mm2)	2.17 x 107 kN/m2
2.	Poisson's ratio of concrete	0.15

Properties of soil

The elastic constants for different types of soil used in interaction analysis are given in Table3

Table -3 Soil Elastic Constant

Soil Type	Soil Designation	Modulus of elasticity (kN/m2)	Poisson ratio
Hard	E-65	65000	0.35
Medium Hard	E-35	35000	0.4
Soft	E-15	15000	0.4

Description of the Elements

To carry out the nonlinear interaction analysis Beam 188 element is used to model the frame and Plane 183 element is used to model the soil, pile and its pile cap. Three types of soil having different modulus of elasticity E-65, E-35 and E-15 are considered. In this analysis to carry out the non-linear analysis contact between the soil and pile is created and the results of the analysis is in the form of Von mises stress contours, Displacement along X direction and Displacement along Y direction, Contact Pressure, and Contact status.

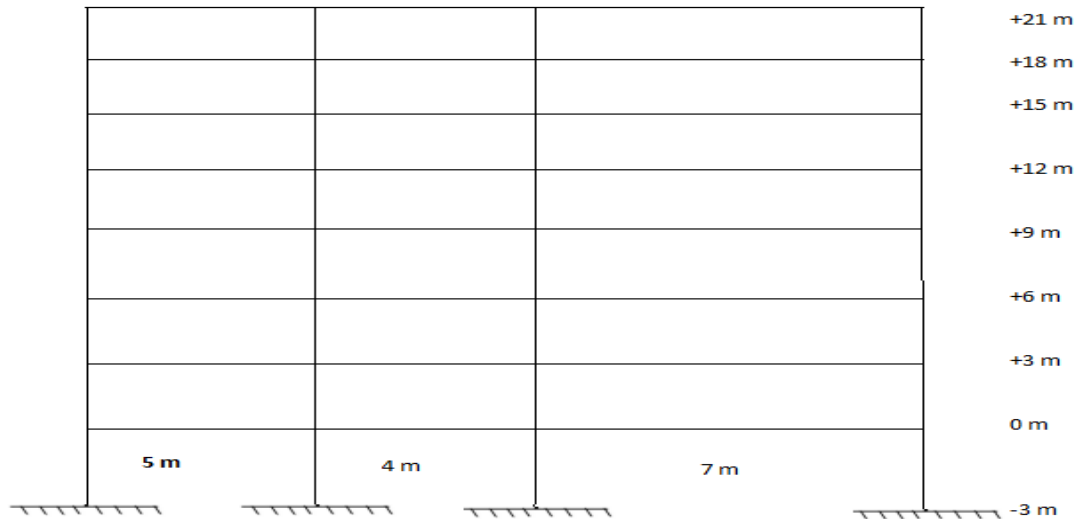


Figure 1. Geometrical details of the frame under analysis

To carry out the nonlinear interaction analysis Beam 188 element is used to model the frame and Plane 183 element is used to model the soil, pile and its pile cap. Three types of soil having different modulus of elasticity E-65, E-35 and E-15 are considered.

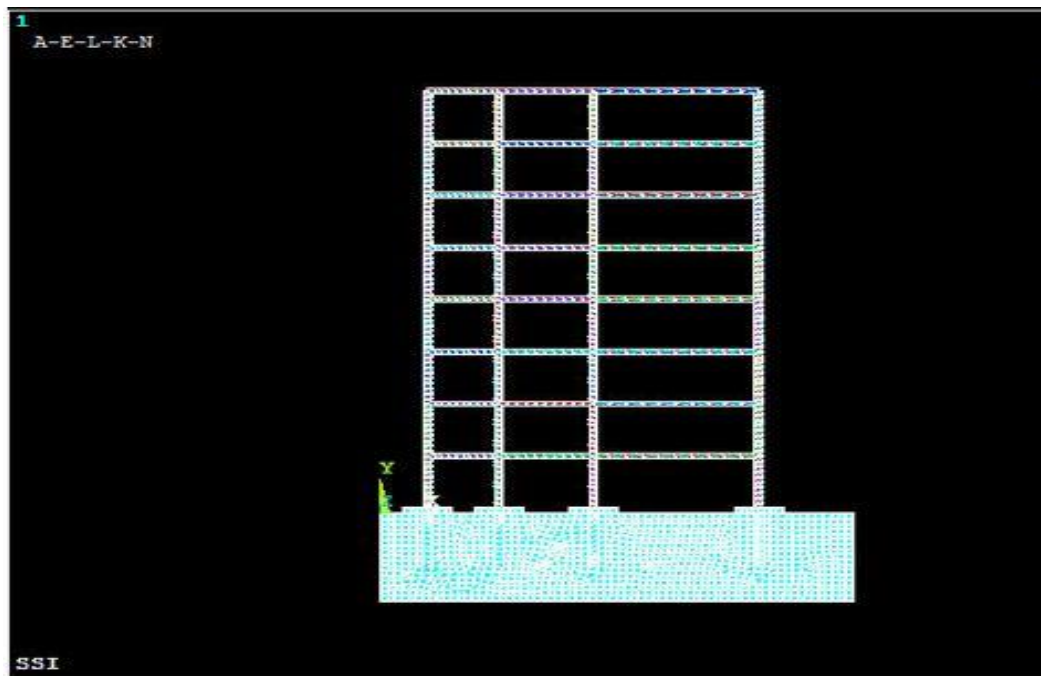


Figure 2 Discretized model of frame for NLIA

3. RESULT DISCUSSION AND CONCLUSION

In this chapter the results of analysis are discussed for the four cases NLIA-65, NLIA-35 and NLIA-15. The main outcomes are:

- Comparison of displacements in X-direction at different footings.
- Comparison of displacements in Y-direction at different footings.
- Comparison of Vonmises at different footings.
- Comparison of Contact pressure at different footings.

Table 4 Displacements in X-Direction

Soil Types	Displacements in X-Direction mm
E-15	1.96
E-35	0.07
E-65	0.18

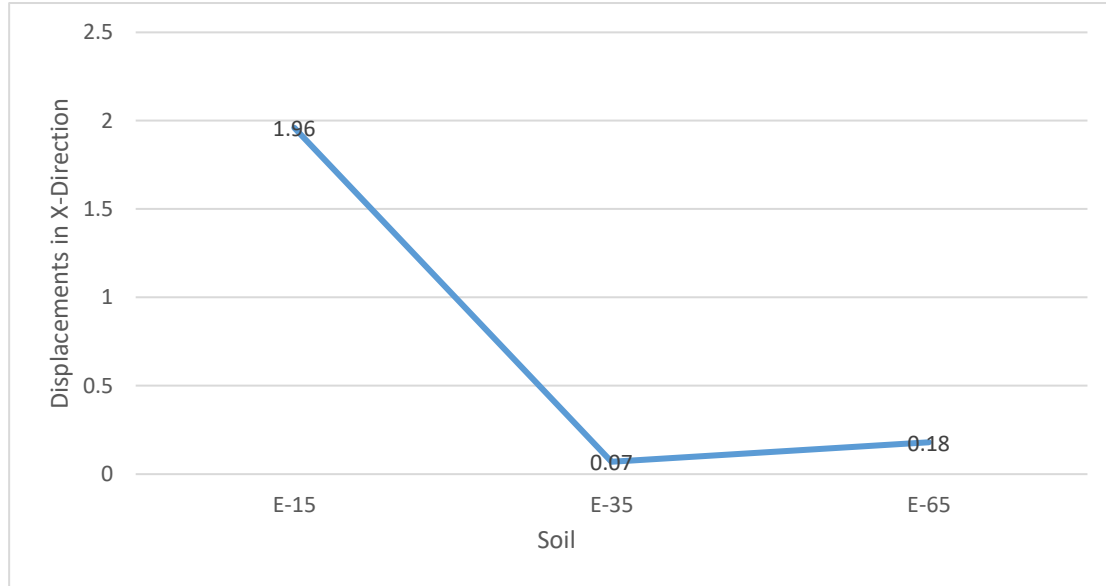


Figure 3 Displacement in X-Direction

Table 5 Displacements in Y-Direction

Soil Types	Displacements in Y-Direction mm
E-15	0.315
E-35	0.016
E-65	0.00965

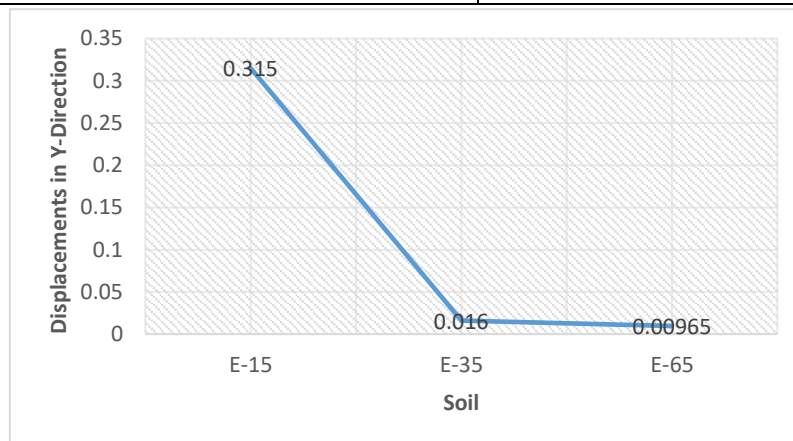


Figure 4 Y-Direction displacement of various soil Von misses stress

Von Mises pressure is a scalar pressure esteem got from the pressure tensor and is utilized in designing and materials science to foresee yielding of materials under complex stacking conditions. It gives a single value to compare against the yield strength of a material, simplifying the analysis of whether a material will yield (plastically deform) under a given load.

Table 6 Von misses stress

Soil Types	Von misses (Mpa)
E-15	57.90
E-35	1.82
E-65	14.62

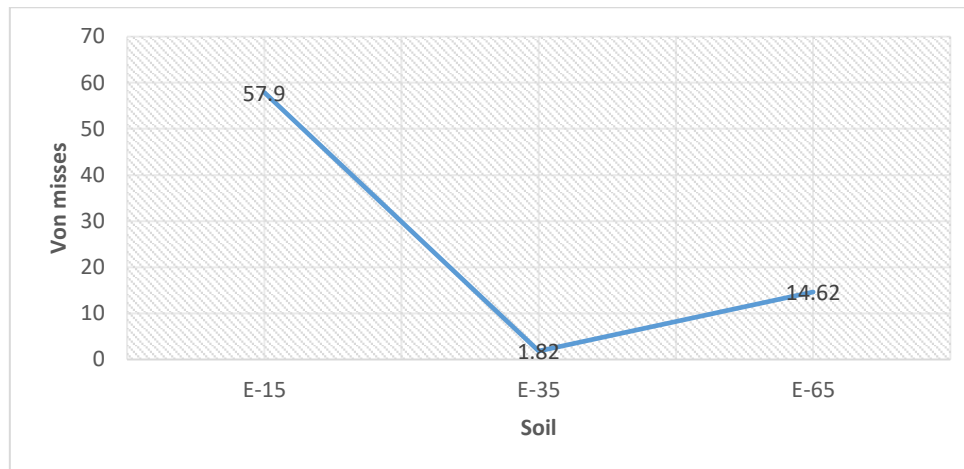


Figure 5 Von misses of various soil

4. CONCLUSIONS MADE FROM THE OBSERVATION

- ❖ Maximum displacement in x-direction and in Y-direction is on soil having modulus of elasticity E-15
- ❖ Contact stresses of soil E-65 are 16% higher than E-35 soil and Contact stresses of E-15 soil are 2.73 times higher than E-65 soil.
- ❖ Vonmisses stresses of E-65 are 8 times higher than E-35 soil and vonmisses stresses of E-15 soil are 4 times higher than E-64 soil.
- ❖ Soil E-35 shows more stiffness than E-65 and E-15.

5. REFERENCES

- [1] C.M. Wang, Y.K. Chow, and Y.C. How, Analysis of rectangular thick rafts on an elastic half-space, Comput. Geotech., 28(3), 2001, 161-184.
- [2] S.C. Dutta, and R. Roy, A critical review on idealization and modeling for interaction among soil-foundation-structure system, Comput. Struct., 80, 2002, 1579-1594.
- [3] M.J. Pender, L.M. Wotherspoon, J.M. Ingham, and A.J. Carr, Shallow foundation stiffness: continuous soil and discrete spring models compared, Proc. of NZSEE Conference, New Zealand, 2006, 1-7.
- [4] K. Nataralan and B. Vidivelli, Effect of column spacing on the behavior of frame-raft and soil systems, J. Appl. Sci., 9(20), 2009, 3629-3640.
- [5] C.S. Desai, and J.G. Lightner, Mixed finite element procedure for soil-structure interaction and construction sequences, Int. J. Num. Meths. Eng., 21(5), 1985, 801-824
- [6] J. Noorzaei, M.N. Viladkar, and P.N. Godbole, Elasto-plastic analysis for soil-structure interaction in framed structures, Comput. Struct., 55(5), 1995, 797-807.
- [7] M.N. Viladkar, G. Ranjan, and R.P. Sharma, Soil-structure interaction in the time domain, Comput. Struct., 46(3), 1993, 429-442.
- [8] W.S. Abdullah, Viscoplastic finite element analysis of complex geotechnical problems, Jordan J. Eng., 5(2), 2011, 302-314.
- [9] IS 1893 (Part 1): 2002. Criteria for Earthquake Resistant Design of Structures. (Part 1:General Provisions and Buildings) (5th Revision).
- [10] ANSYS User's Manual 10.0, Release 10.0, ANSYS, Inc., 2005
- [11] Aldo Fernández Limés Dhiraj Ahiwale "soil structure interaction. Generalities" September 2023 Publisher: CUJAE Editor: Rolando Serra Toledo ISBN: 9789592616226.
- [12] Baban Bapir^{1*} Lars Abrahamczyk¹ Torsten Wichtmann² Luis Felipe Prada-Sarmiento² "art review of modeling techniques and studies on seismic response of building structures.
- [13] Ali Asghar Firoozi "Soil-Structure Interaction: Understanding and Mitigating Challenges" February 2024 DOI: 10.5772/intechopen.112422 In book: Challenges in Foundation Engineering - Case Studies and Sustainable Practices Publisher: Intech Open.
- [14] Francesco Cavalieri ^a, António A. Correia ^b, Helen Crowley ^c, Rui Pinho "Dynamic soil-structure interaction models for fragility characterisation of buildings with shallow foundations" Soil Dynamics and Earthquake Engineering Volume 132, May 2020, 106004